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LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

LAND USE AND CROP CLASSIFICATION ANALYSIS FOR THE UPPER LITANI RIVER BASIN

(MAY 2011 – OCTOBER 2011)

FEBRUARY 2012
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by International Resources Group (IRG) under Contract EPP-I-00-04-00024-00 order no 7.

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ACRONYMS

GIS	Geographic Information System
RS	Remote sensing
GPS	Global Positioning System
IRG	International Resource Group
USGS	United States Geological Survey
USAID	United States Agency for International Development

FOREWORD

The present report was prepared by Wassim Katerji, and Dr Tom Sheng (Computer Assisted Development Inc, CADI), both GIS/remote sensing specialists. It was prepared under subcontract with International Resources Group (IRG), the main contractor under the Litani River Basin Management Support (LRBMS) Program, a USAID-funded program in Lebanon (Contract EPP-I-00-04-00024-00 Task Order No. 7 under the Integrated Water and Coastal Resources Management Indefinite Quantity Contract (IQC) II.

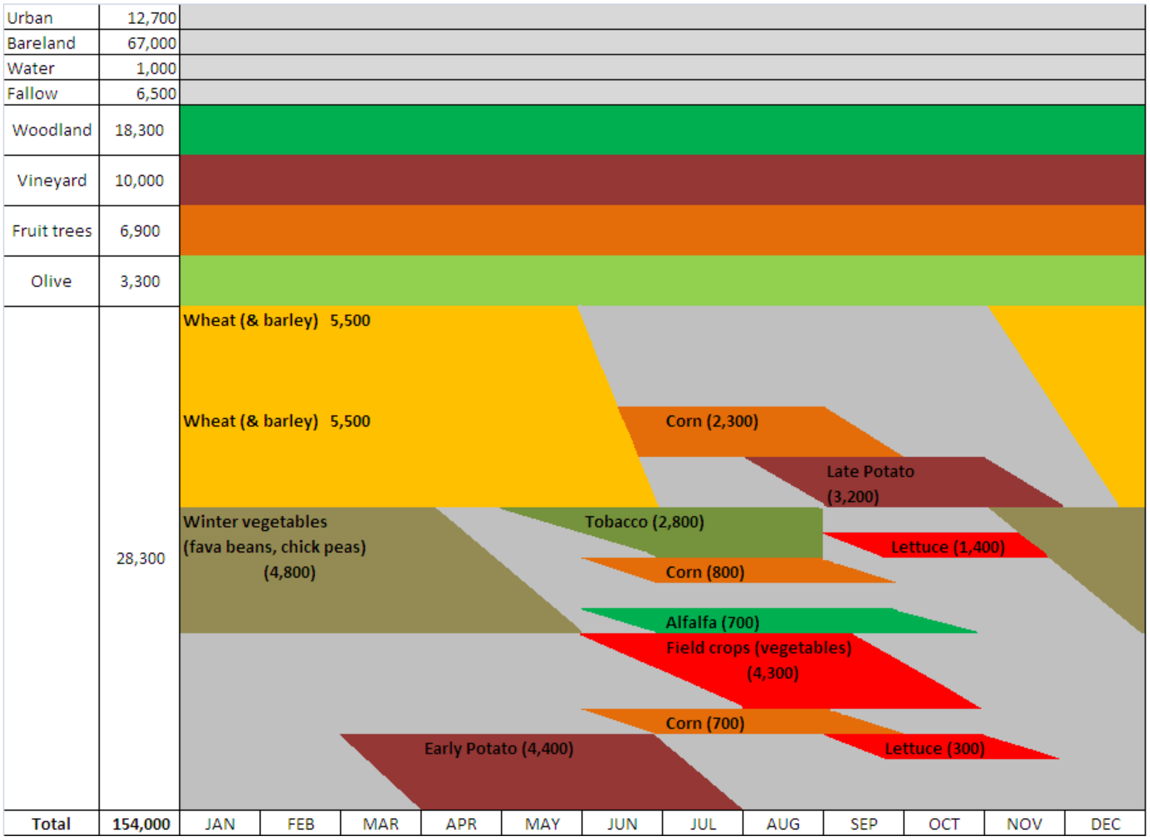
EXECUTIVE SUMMARY

Current water monitoring in the Upper Litani River Basin remains limited, notably regarding groundwater. Irrigation developed significantly in the last 20 years using pumping from individual wells, with a consequent lowering in water levels. But limited data exists as to the rate of withdrawals, and thus as to the sustainability of this practice. Thousands of wells exist and most of them are illegal. Very few are equipped with flow meters.

While a field-based inventory of wells would be an exhaustive approach, coupled with systematic monitoring, it would be extremely costly and difficult to implement. An alternative approach, used in many countries, is to evaluate water consumption based on actual cropping patterns and estimated water needs for each type of crop. This approach provides reasonable estimates but requires good information on cropping patterns. Again a common approach with the development of satellite imagery is to use satellite pictures because they can provide exhaustive and detailed coverage of large areas and, once calibrated through field sampling, define cropped areas per type with good accuracy, and thus map the entire cropping patterns, both geographically and over time.

In the case of the Upper Litani River Basin, a review of satellite data led to the choice of acquiring three sets of 2011 pictures (May-June, July-August, and September-October) from RapidEye with a 5 m spatial resolution while collecting ground truth data using a hand-held GPS receiver.

The results were checked for accuracy and led to cropping maps which can be found in the Annexes. Based on these maps, the following cropping calendar was established:



Assessing cropped areas and cropping patterns is essential for a better understanding of water requirements in the Litani River Basin. It should be carried out on a regular basis, at minima every 2-3 years and optimally every year as weather, input availability, and economic factors can push farmers to significantly change their cropping from year to year. Free satellite pictures (Landsat) can be used and LRA staff should be able to carry out this activity on a regular basis.

ملخص تنفيذي

لا تزال القياسات المائية المتبعة حالياً في الحوض الاعلى لنهر الليطاني محدودة ، لا سيما تلك المتعلقة بسحوبات المياه الجوفية. وفيما شهدت عملية الري توسعاً ملحوظاً في السنوات العشرين الاخيرة ، من خلال إعتماد الضخ بواسطة الابار الجوفية ، سجل إنخفاض في مستوى الطبقات المائية . غير أن المعلومات الخاصة بالكميات المسحوبة من المياه الجوفية عن طريق الابار لا تزال محدودة جداً ، بالإضافة إلى عدم وجود إثباتات حول هذه التقنية سواء من ناحية فعاليتها أو من ناحية استمراريتها على مدى البعيد.

وفيما يعتبر المسح الحقلي للابار عملية صعبة وشاقة ،هذا إذا ما تم اتباعها بقياسات السحوبات المائية ، فإن عملية المسح الحقلي تعتبر مكلفة إيضاً وصعبة التنفيذ. لذلك، قامت بعض الدول بإعتماد طرق أخرى من أجل تحديد المساحات المزروعة والاستهلاكات المائية لكل محصول زراعي وفق الية عمل واقعية انما تحتاج إلى معلومات وفيرة ودقيقة عن المساحات المزروعة ونوع الزراعات.

بالإضافة إلى ذلك ، تم موئخراً إعتماد الصور الجوية من أجل مسح الاراضي الزراعية بواسطة الاقمار الاصطناعية وتحديد كميات الاستهلاك من مياه الري. غير أن هذه التقنية تتطلب زيارات حقلية من أجل التعرف عن كثب عن نوع المزروعات ، وبالتالي وضع خريطة تبين توزيع الزراعات ضمن الحدود الجغرافية المحددة وتغير الزراعات عبر فصول السنة.

فيما يخص الحوض الاعلى لنهر الليطاني ، فقد ادت المراجعات في هذا الخصوص للمعلومات الصادرة عن الاقمار الاصطناعية إلى إختيار ثلاثة نماذج من الصور الجوية خلال العام 2011 عن أشهر ايار ، حزيران ، تموز ، آب ، أيلول وتشرين أول ، وذلك عن طريق القمر الاصطناعي 'رابيد آي' والذي يمتاز بدقة إستشعار تصل إلى حدود ال–5 أمتار. وقمنا بمقارنة الصور الجوية مع المعلومات الحقلية التي استحصلنا عليها بواسطة جهاز تحديد المواقع الجغرافية. ونتيجة ذلك، قمنا بإعداد

خرائط تبين أمكنة تواجد المزروعات وتوزيعها ضمن الإطار الجغرافي المحدد في هذه الضرر ، وتم بالتالي وضع روزنامة زراعية وضحة المعالم للحوض الاعلى لنهر الليطاني.

اظهرت نتائج هذه الدراسة مدى أهمية معرفة تحديد المساحات المزروعة والدورات الزراعية المتبعة على مدار السنة في الحوض الاعلى لنهر الليطاني ، مما يساعد في تحديد كميات مياه الري التي يستهلكها النبات. كما على القيمين على المصلحة الوطنية لنهر الليطاني أن يقومو بمعاودة هذه الدراسة، اقله مرتين أو ثلاثة كل فترة سنتين أو ثلاثة، والافضل مرة كل سنة باعتبار أن المعطيات المناخية تتغير بين سنة وأخرى، بالإضافة إلى توافر عناصر الانتاج الذراعي وكلفة الانتاج.

يمكننا أن نستخلص من هذه الدراسة أن الصور الجوية يمكن إعتماده بشكلٍ دوري من أجل تحقيق الاهداف المبينة أعلاه، علماً أن بعض الصور الجوية التي يقوم بإصدارها بعض الاقمار الاصطناعية هي مجانية ولا يترتب عليها أي اعباء مالية. لذلك، على القيمين والمسؤولين على المصلحة الوطنية لنهر الليطاني أن يعتمدو تقنية التصوير الجوي في أعمالهم.

1. INTRODUCTION

1.1. PROJECT BACKGROUND

International Resource Group (IRG) under the USAID/Lebanon funded Litani River Basin management Support Program (LRBMS, Contract No. EPP-I-00-04-00024-00 Task Order 7) is responsible for assisting the Litani River Authority (LRA) in Lebanon to improve water resources management. The period of performance is September 29, 2009-September 30, 2012.

The objective of this Task Order is to set the ground for improved, more efficient and sustainable basin management at the Litani river basin through provision of technical support to the Litani River Authority and implementation of limited small scale infrastructure activities. To achieve the LRBMS program objectives, the Contractor shall undertake tasks grouped under the following four components:

1) Building Capacity of LRA towards Integrated River Basin Management
2) Long Term Water Monitoring of the Litani River
3) Integrated Irrigation Management with two sub-components:
    a. Participatory Agriculture Extension Program: implemented under a Pilot Area: West Bekaa Irrigation Management Project
    b. Machghara Plain Irrigation Plan
4) Risk Management with two sub-components:
    a. Qaraoun Dam Monitoring System
    b. Litani River Flood Management Model

1.2. ACTIVITY BACKGROUND AND OBJECTIVES

Irrigation is the main type of water use in the Litani River Basin. There is limited information as to actual cropped areas, in general and per type of crops. Yet this information is critical to assess water needs and thus lead the proper planning and management of water resources in the River Basin. The main objective of this activity is thus to develop a simple yet relative accurate procedure for identifying cropping areas and cropping patterns in the Litani River Basin, using remote sensing and image processing technologies.

Different approaches can be considered to perform this task, mainly remote sensing and complete field survey. The first approach was chosen because of the following advantages:

- **Efficient and Effective:** It's much faster to analyze satellite images and classify them according to various crop types, based on a few ground truth data collection field trips, rather than visit each individual land plot and record its crops. The remote sensing/image processing approach is possible because each type of crop has a unique spectral signature that can be detected and recorded in a multi-spectral satellite image.

- **Completeness:** All the area of study can be covered by satellite images, while in an exhaustive field survey, not all locations may be accessible.

The major focus of this study was on the crop classification and land use change from one season to another. The crops included in the study were winter wheat, potato, tobacco, field crops and vegetations (tomatoes, cabbage, lettuce, cucumber, eggplants, etc), olive trees, fruit trees, vineyard and corn. Other non-crop classes (i.e., bareland, forest, water and urban areas) were also included and analyzed to provide a more comprehensive overview of the landuse in the study area.

1.3. STUDY AREA

This study was carried out in the Upper Litani Basin. It covers 1,540 km^2 in the central and south Bekaa valley and is the main agricultural region of Lebanon. The proceeding map depicts the general topography features of the area. The lower river basin (south of Qaraoun Lake) consists of a narrow valley with limited irrigation activities. It has only a few hundred irrigated hectares in the hilly catchment of Wadi el Debbe and access to these areas are restricted.

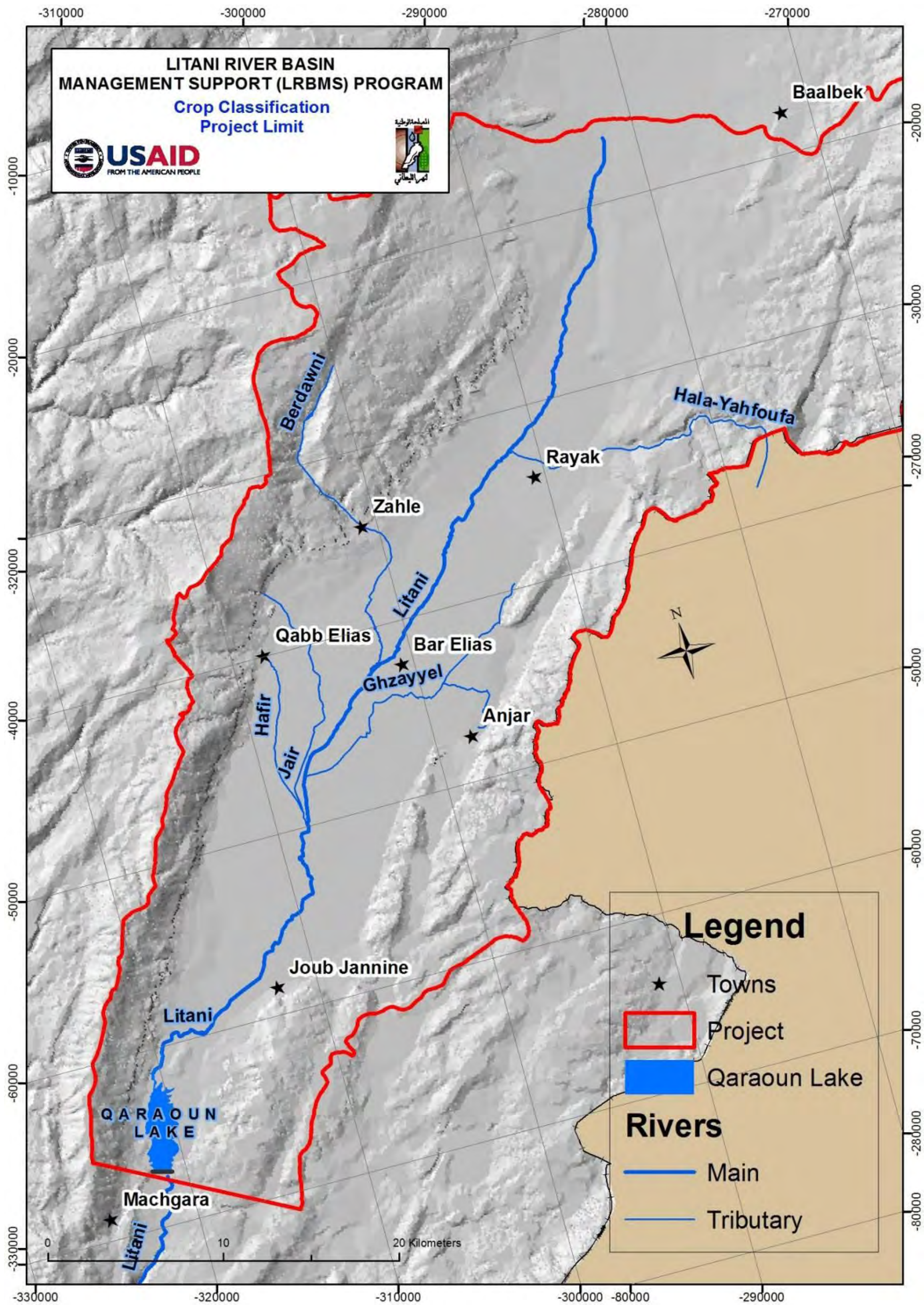


Figure 1: Upper Litani Basin

1.4. TIME FRAMES

The crop classification analysis was repeated at three different time periods in 2011: May - June, July - August, and September - October. These three periods were chosen to best reflect the peak crop growing seasons for winter, spring and summer in order to identify crop types for each season and to detect changes from season to season. The appropriate selection of data acquisition dates was an integral component of the study success. Using multi-season imagery approach has also shown higher precision for non-crop classes such as woodland, urban and bare land over single-date classification.

2. METHODOLOGY

2.1. CROP DATA COLLECTION USING GPS

Ground-based crop/non-crop and site data were collected using a GPS receiver. The ground truth sites were semi-randomly selected in the study area for each of the 3 sets of images to ensure that the data acquisition was geographically disbursed for each and every type of crops/non-crops. A total of 217 locations (lat and long) of major crops were captured during the field surveys. In addition to crop location data, photos of the crops at sampling sites were taken to provide more information on the crop conditions in the field. The collected data recorded, reviewed, and processed to build the crop spectral signatures for the image classification. The spectral signatures are sets of pixels that represent what is recognized as a discernible pattern, or potential landuse class. These signatures were used later for supervised maximum likelihood classification to extract and classify each and every pixel from the raw satellite image to build the thematic landuse maps.

The collection of ground truth data was carried out in multiple locations for each of the crops in the study area. The main reasons for collecting site data of the same crop type in multiple locations were:

1. The same type of crop may exist along the valley at various growth stages; depending on the date that crop was planted. The spectral range varies in accordance with the growth stages of the crop. Although the differences should be small, they might cause ambiguity when classifying the satellite image if not included. In general, the more pixels that can be used for signature generation, the better the statistical representation of each crop/non-crop class. Taking several samples of the same crop generates a "good" signature that represents a crop in different growth stages existing in the study area at a specific time period.
2. The satellite image for the study area was generated by a mosaic of 13 satellite image tiles taken at different dates within 10 days. Given the different atmospheric and climatic situations mainly cloud coverage and sun light reflection, the spectral range for the same crop may differ at each date. To resolve this issue, location samples were collected for each image with different dates for each crop type. The combination of these spectral ranges for each crop on different dates enable us to generate a more suitable set of signatures for classifying the mosaiced satellite image with tiles taken at different dates.

After each field assessment visit, the collected crop/non-crop ground truth sites (waypoints) were uploaded to GIS software, and created a point layer and overlaid on top of the satellite image for visual inspection. If the collected sites did not cover all the crop/non-crop classes, or if some of them were misplaced due to some unexpected GPS technical failures, additional field trips would have been taken to fulfill the missing data.

2.2. IMAGE CLASSIFICATION

The objective of the image classification is to categorize all pixels in a digital satellite image into one of several landuse classes (crop and non-crop). This categorized data may then be used to build thematic maps of landuse present in a satellite image. Two main image classification methods in remote sensing are unsupervised classification and supervised classification.

Unsupervised classification is an image classification method which examines a large number of unknown pixels and divides them into a number of spectral classes based on natural grouping presented in the image values. It does not require the user to specify any information about the features contained in the images. The user simply identifies which bands ArcGIS should use to create the classifications, and how many classes to categorize the land use features into. The main idea is that spectral values within a given landuse type should be close together, whereas data in different classes should be comparatively separated. The classes that results from unsupervised classification are spectral classes; the identity of the spectral class will not be initially known. It must be compared classified data to other reference data such as maps, aerial photographs and ground truth site data to determine the identity of the spectral classes.

In this study, the satellite image pixels are divided into 20 spectral classes and compared with data from other sources to determine the identity of the spectral classes. The user at this point has to make decisions on which classes can be grouped together into a single landuse type. In this study, eight of the 20 spectral classes were re-assigned to the 12 major landuse types in the area. The results were then used to identify locations for collecting ground truth data for the 12 landuse types.

With supervised classification, the individual processing the image identifies examples of the landuse classes of interest in the image. These are called the training sites. GIS software is then used the training sites with multi-spectral bands to create spectral signatures from the specified areas. Once signature has been established for each landuse class, the image is then classified by examining the reflectance value for each pixel on each band and making decision about which of the signatures it represents most.

As discussed above, spectral signatures are developed from specified locations in the image. It is essential that the individual processing the image is familiar with the study area and has prior knowledge of the landuse classes in the study area. Ground validation is the process of comparing what is seen in the satellite image with what was actually present at the time image was recorded; this process makes the classification task more efficient and more accurate. Hence, collection of ground truth site data for each landuse class is a must before starting any classification.

The results from the supervised classification are compared to the ground truth data and a summary on how close the results matched the site data is prepared. When the results do not match the ground truth data then the training polygons are evaluated, adjusted, deleted, and added. Then the supervised classification is repeated with the revised training sites and its results compared to the ground truth data. This process is repeated several times until the results matched closely. Other ancillary data is also used to compare the results, such as existing landuse coverage and agriculture classification.

Once acceptable results are reached, final digital map preparation functions can be carried out, which includes filtering small areas and smoothing the boundaries between various crop types, in order to clean up the raster image. Then, the raster image of landuse can be converted into a vector map with multiple landuse polygons of interest, where areas of each landuse polygons are computed. By combining and summarizing the areas, a table containing the total area per crop type can be generated.

3. DATA COLLECTION

An extensive review of appropriate satellite data for this study was performed over a period several months. The available multi-spectral satellite imagery options at the time were: Landsat TM (30 m), FORMOSAT (8 m), RapidEye (5 m), IKONOS (4 m), Astrium/SPOT (2.5 m), QuickBird (2.4 m), GeoEye (1.65 m) and WorldView (1.8 m). With the given project budget limitation and technical analysis requirements, an optimal choice was made by acquiring satellite imagery with 5 m spatial resolution from RapidEye and collecting ground truth data using a hand-held GPS receiver.

3.1. RAPIDEYE SATELLITE IMAGERY

Digital image data from RapidEye AG were acquired over the study area for three time periods in 2011 (May-June, July-August, and September-October) as discussed above. The RapidEye is multi-spectral, high-resolution, orthorectified imagery, reasonable priced comparing with other high-resolution satellite image product and earth surface area can be revisited daily. The spatial resolution of the images is 5-m with a depth of 12 bits per channel. Spatial resolution is defined as the minimum size of terrain features that can be distinguished from the background in an image, or the ability to differentiate between two closely spaced features in an image. A nearly fully-automated pre-processing system generates orthorectified and atmospherically corrected image tiles within 48 hours after acquisition. The multi-spectral imagery of RapidEye includes commonly used spectral bands in the blue, green, red, and near infrared (NIR) bands, plus a fifth band the red-edge spectral band between the red and the NIR band, which measures variances in vegetation, allowing for species separation and monitoring vegetation health. The details of the five spectral images are:

Band #	Name	Spectral Range (nm)
1	Blue	440 - 510
2	Green	520 – 590
3	Red	630 – 685
4	Red-Edge	690 – 730
5	Near Infrared	760 – 850

Table 1: Rapid Eye Bands

A total of 13 image tiles were provided by RapidEye AG to cover the footprint of the study area for each time period. The three sets of multi-spectral satellite images were mosaic, process, classified, and compared to ground truth landuse data.

3.2. GPS DATA

A handheld GPS receiver (Garmin GPSMAP 60CSx) was used to collect field locations of the various crop types and other land uses. The GPSMAP® 60CSx is one of popular models for outdoor use. This unit features a removable microSD card for detailed mapping memory and a waterproof, rugged housing. The microSD card slot is located inside the waterproof battery compartment. Users can upload GIS map data and transfer routes and waypoints through the unit's fast USB connection.

In addition, this unit features a highly sensitive GPS receiver that acquires satellites faster and lets users track their location in challenging conditions, such as heavy foliage or deep canyons. The GPSMAP 60CSx also provides a barometric altimeter for extremely accurate elevation data and an electronic compass that displays an accurate heading while standing still. The unit positional accuracy is up to 5 m, which is comparable with RapidEye image spatial resolution.

4. RESULTS

In order to assess the results below, it is important to have a good understanding of the agronomic conditions and the cropping system in the study area. It is only then a comparison of what crops are expected in the field vs. crops identified from the satellite images can be made.

4.1. INDICATIVE CROPPING

Before going to the field and collecting sample points, it is essential to have a preliminary knowledge of what crops would be present, especially in terms of estimated periods of cultivation and harvest, and cropping patterns (i.e. what kind of crops can be cultivated after another type in the same land).

Agriculture in the Litani River Basin mainly consists of:

- Perennial crops such as fruit trees (apple, pear, cherry, peach), vineyards and olive trees;
- Winter cereals (wheat, barley) and winter cereals (lentils, fava beans and chickpeas); and
- Summer vegetables (tomatoes, cabbage, onion, etc.), corn, tobacco and potato (both early in the spring or later in the Fall)

Below is data from the 'Atlas Agricole' (2005):

<table>
<tr><th>Crop type</th><th>Area (ha)</th></tr>
<tr><td>Winter Wheat</td><td>25,000</td></tr>
<tr><td>Olive Trees</td><td>2,000</td></tr>
<tr><td>Fruit Trees</td><td>8,000</td></tr>
<tr><td>Vineyards/Grape yards</td><td>5,000</td></tr>
<tr><td>Spring Single Crop</td><td rowspan="2">15,000</td></tr>
<tr><td>Spring/Summer Double Crop</td></tr>
<tr><td>total</td><td>55,000</td></tr>
</table>

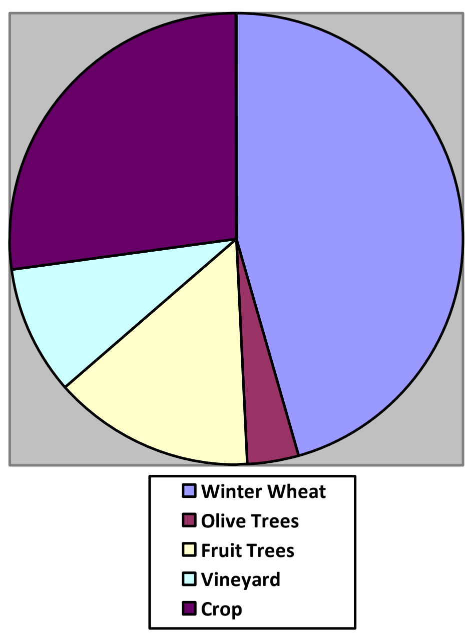


Table 2: 2005' Atlas Agricole

From field observations and interviews, nowadays some single cropping focuses on higher value irrigated summer crops (early potato and vegetables), while double cropping is widespread:

1. Winter cereals followed by corn or late potato
2. Winter vegetables followed by tobacco, corn or alfalfa in summer

Triple cropping is rare but can include winter vegetables, tobacco (Spring-Summer) and lettuce (Fall).

4.2. RAW RESULTS

4.2.1. FIRST SET: MAY-JUNE 2011

From the first set of satellite images, the following main crop and non-crop classes were identified. The acreage of each crop and non-crop is summarized in the table below. The main seasonal crops were winter wheat, potato, field crop and tobacco with total acreage of 20,482 ha, which is about 50% of the cropped area.

No.	Type	Area (ha)	%	% Cropped Area
1	Bareland	67,015 ha	43.5%	
2	Corn	305 ha	0.2%	0.6%
3	Fallow	14,378 ha	9.3%	26.1%
4	Field Crop	4,849 ha	3.1%	8.8%
5	Fruit Tree	6,900 ha	4.5%	12.5%
6	Olive	3,298 ha	2.1%	6.0%
7	Potato	3,524 ha	2.3%	6.4%
8	Tobacco	777 ha	0.5%	1.4%
9	Urban	12,704 ha	8.2%	
10	Vineyard	9,966 ha	6.5%	18.1%
11	Water	1,031 ha	0.7%	
12	Wheat	11,006 ha	7.1%	20.0%
13	Woodland	18,298 ha	11.9%	

Table 3: 1st Set Results

4.2.2. SECOND SET: JULY-AUGUST 2011

From the second set of satellite images, the following main crop and non-crop classes were detected. The acreage of each crop and non-crop is summarized in the table below. The main seasonal crops were potato, field crop, tobacco and corn with total acreage of 18,449 ha, which is about 48% of the cropped area:

No.	Type	Area (ha)	%	% Cropped Area
1	Bareland	67,015 ha	43.5%	
2	Corn	3,776 ha	2.5%	6.9%
3	Fallow	20,368 ha	13.2%	37.2%
4	Field Crop	3,951 ha	2.6%	7.2%
5	Fruit Tree	6,900 ha	4.5%	12.6%
6	Olive	3,298 ha	2.1%	6.0%
7	Potato	3,640 ha	2.4%	6.7%
8	Tobacco	2,803 ha	1.8%	5.1%
9	Urban	12,704 ha	8.2%	
10	Vineyard	9,966 ha	6.5%	18.2%
11	Water	1,031 ha	0.7%	
12	Woodland	18,298 ha	11.9%	

Table 4: 2nd Set Results

4.2.3. THIRD SET: SEPTEMBER-OCTOBER 2011

From the third set of satellite images, the following main crop and non-crop classes were detected. The acreage of each crop and non-crop is summarized in the table below. The main seasonal crops were field crop and corn with total acreage of 9,324 ha, which is about 31% of the cropped:

No.	Type	Area (ha)	%	% Cropped Area
1	Alfalfa	734 ha	0.5%	1.3%
2	Bareland	67,015 ha	43.5%	
3	Corn	1,188 ha	0.8%	2.2%
4	Fallow	24,938 ha	16.2%	45.4%
5	Field Crop	4,770 ha	3.1%	8.7%
6	Fruit Tree	6,900 ha	4.5%	12.6%
7	Olive	3,298 ha	2.1%	6.0%
8	Potato	3,179 ha	2.1%	5.8%
9	Urban	12,704 ha	8.2%	
10	Vineyard	9,966 ha	6.5%	18.1%
11	Water	1,031 ha	0.7%	
12	Woodland	18,298 ha	11.9%	

Table 5: 3rd Set Results

4.3. ACCURACY ASSESSMENT

The field samples are compared to the result generated by the supervised classification in order to assess the overall and type-related accuracy of the results. The below shows the details of the assessment, where the count represent the number of field collected samples per type and for a specific set, the match represent the samples that matched the supervised classification, and the percentage represent the percentage of matching samples with respect to the overall collected samples:

	1st Set			2nd Set			3rd Set			Overal
Type	Count	Match	%	Count	Match	%	Count	Match	%	Match %
Bareland	3	3	*100%*	8	8	*100%*	7	7	*100%*	**100%**
Corn	-	-	-	2	1	*50%*	1	1	*100%*	**67%**
Fallow	5	5	*100%*	9	8	*89%*	17	14	*82%*	**87%**
Field Crop	2	2	*100%*	15	14	*93%*	7	3	*43%*	**79%**
Fruit Tree	6	4	*67%*	4	3	*75%*	11	9	*82%*	**76%**
Olive	4	4	*100%*	4	3	*75%*	7	5	*71%*	**80%**
Potato	3	3	*100%*	11	11	*100%*	-	-	-	**100%**
Tobacco	1	1	*100%*	3	3	*100%*	-	-	-	**100%**
Urban	6	6	*100%*	6	6	*100%*	7	7	*100%*	**100%**
Vineyard	3	3	*100%*	11	11	*100%*	19	15	*79%*	**88%**
Water	4	4	*100%*	3	3	*100%*	6	3	*50%*	**77%**
Wheat	9	7	*78%*	-	-	-	-	-	-	**78%**
Woodland	4	4	*100%*	6	6	*100%*	3	3	*100%*	**100%**
Total	**50**	**46**	***92%***	**82**	**77**	***94%***	**85**	**67**	***79%***	**88%**

Table 6: Accuracies

The overall accuracies of the 1st, 2nd and 3rd sets are: 92%, 94% and 79% respectively. The results of the 1st 2 sets are highly accurate, whereas the results of the 3rd set were initially less accurate at 79%.

This drop of accuracy in the 3rd set is mainly due to the noticeable mismatches at the level of field crops, where the match is only 43%. The mismatch was found to be due to the presence of fodder crops (alfalfa), which were thereby included. Final accuracy for set 3 thus increased to 85%.

4.4. CROP CHANGES AND CROPPING CALENDAR

In order to understand cropping patters, one needs to know the succession of crops in the same plots (what comes after what). It is also a useful tool to check the accuracy of the findings (a given crop can follow another one but many combinations are not possible due to conflicting crop requirements in terms of planting and harvesting times).

The remote sensing approach allows assessing the succession of crops in the same plots. The table below provides in this sense a comparison of the three datasets:

Set 1	Set 2	Set 3	Area (ha)	%
Corn	Corn	Fallow	305	0.2%
Fallow	Corn	Fallow	429	0.3%
Fallow	Fallow	Field Crop	831	0.5%
Fallow	Field Crop	Fallow	1,457	0.9%
Fallow	Field Crop	Field Crop	2,184	1.4%
Fallow	Potato	Fallow	927	0.6%
Fallow	Tobacco	Fallow	998	0.6%
Fallow	Tobacco	Field Crop	1,029	0.7%
Field Crop	Corn	Corn	619	0.4%
Field Crop	Corn	Fallow	144	0.1%
Field Crop	Fallow	Alfalfa	734	0.5%
Field Crop	Fallow	Fallow	3,238	2.1%
Field Crop	Field Crop	Corn	84	0.1%
Potato	Fallow	Fallow	476	0.3%
Potato	Fallow	Field Crop	108	0.1%
Potato	Field Crop	Field Crop	226	0.1%
Potato	Potato	Corn	222	0.1%
Potato	Potato	Fallow	2,492	1.6%
Tobacco	Tobacco	Fallow	385	0.3%
Tobacco	Tobacco	Field Crop	392	0.3%
Wheat	Corn	Corn	263	0.2%
Wheat	Corn	Fallow	2,016	1.3%
Wheat	Fallow	Fallow	5,549	3.6%
Wheat	Fallow	Potato	3,179	2.1%
7,855	14,115	18,415	28,285	
20,430	**14,170**	**9,870**		
Non Changers				
Bareland			67,015	43.5%
Fallow			6,524	4.2%
Fruit Tree			6,900	4.5%
Olive			3,298	2.1%
Urban			12,704	8.2%
Vineyard			9,966	6.5%
Water			1,031	0.7%
Woodland			18,298	11.9%

Table 7: Crop changes

From this table, we can then define the cropping calendar which is found below:

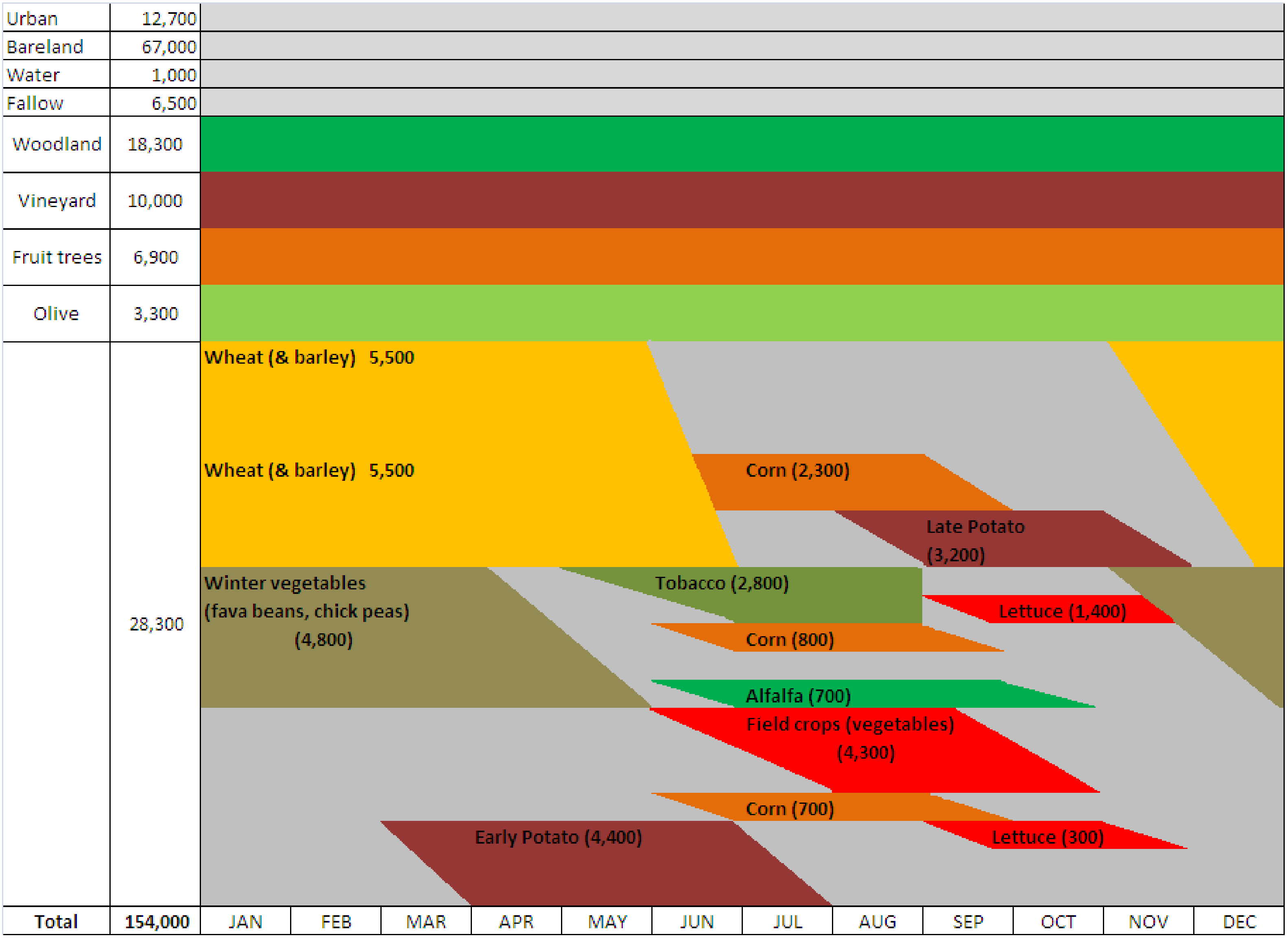


Table 8: Cropping Calendar for the Litani River Basin in 2011

5. FOLLOW-UP

Assessing cropped areas and cropping patterns is essential for a better understanding of water requirements in the Litani River Basin. It should be carried out on a regular basis, at minima every 2-3 years and optimally every year as weather, input availability, and economic factors can push farmers to significantly change their cropping from year to year.

5.1. LEVEL OF EFFORT

While the initial effort was somewhat time-consuming in order to develop the proper methodology, translating one set of satellite pictures from the Litani River Basin into a table of cropping areas does not require a large level of effort: about three days of field work (preferably by both agronomist and remote sensing specialist) and then 7-8 days of image processing by the remote sensing specialist).

5.2. FUTURE WORK

The study is planned to be repeated for 2012. It will follow the same methodology done in the 2011 survey, with the following adjustments:

- Using Landsat 7 satellite images instead of RapidEye. While Rapideye has a better resolution (5 meters compared to 15 meters cell-size), it requires some budget to purchase, while Landsat pictures are available online for free, even if of coarser resolution.
- Adding new classes: Food Legumes and Bulb crops. Those types were previously included within the field crops. However, it was recommended to separate them into new classes, as this diversification will give more information, especially concerning the crop calendar.

Based on the 2011-2012 comparison, a final procedure will be prepared and taught to LRA staff, in order for them to repeat the task on a regular basis.

APPENDIX A: STEPWISE PROCEDURE FOR CROP CLASSIFICATION USING SATELLITE IMAGERY

A.1 PRE-PROCESSING

The phase is mainly concerned with preparing the satellite image, prior to the field sampling. This phase is very important to be made first, as it gives the analyst a general view of the area of study, the various land classifications (number of classes), and will assist him in choosing the locations of the field samples, that will occur in the next phase.

The performed tasks in this phase are:

1. Composting image bands (RapidEye 3, 2, and 1) for each scene using ArcMap tools (Data Management Tools>Raster>Composite Bands) to generate natural color images.

2. Performing ArcMap Mosaic function (Data Management Tools> Raster>Mosaic to New Raster, Pixel Type: 8_BIT_UNSIGNED, Number of Bands: 3, Mosaic Method: MAXIMUM and Mosaic Colormap Mode: First) to combine the various scenes into one raster image.

3. Extracting the combined image by an area of interest (i.e., Upper Litani Basin) using ArcMap Spatial Analysis Tools>Extraction>Extract by Mask.

4. Creating general spectral classes (i.e., 15-20 numbers) based on the multi-band color pixel values (all 5 bands) with ArcMap Spatial Analysis Tools>Multivariate>ISO Cluster.

5. Performing an unsupervised classification of the mosaiced raster image to identify broad land use and cover classes (i.e., villages, roads, canals, cropped areas, and fallow areas) using ArcMap Spatial Analysis Tools>Multivariate>Maximum Likelihood Classification with the ISO Classes plus available ancillary data.

6. Selecting field sites for ground truthing to identify the spectral classes resulted from the unsupervised classification.

7. Setting up the GPS receiver (i.e., install new batteries, map projection, units, time, and date, etc).

8. Transferring the available shapefiles (i.e., Litani River Basin, Litani rive network, major roads and the selected ground truth sites) to the GPS receiver.

9. Setting the digital camera (i.e., time, date and extra memory cards).

A.2 FIELD SAMPLING

This phase is mainly concerned with collecting ground truth data, to match them with the various spectral classes identified from the satellite image in the previous phase.

The specific tasks in this phase are:

1. Arranging proper transportation for the field work.

2. Conducting field surveys (ground truthing) to identify main crops in the sampling sites and mark their locations with the GPS receiver (i.e., waypoints or tracks).

3. Connecting the GPS unit using a USB cable to the ArcGIS laptop computer. Then import the tracks/waypoints to ArcMap from the GPS unit using the DNR Garmin software and save these waypoints/tracks as Shapefiles daily.

4. Projecting the waypoint/track shapefiles from geographic coordinate system (WGS 1984) to UTM Zone 36N using ArcMap, if necessary.

5. Overlaying the waypoint/track shapfiles on the satellite imagery. On the screen, visually check that the tracks/waypoints are correctly aligned on the satellite map daily. If not, correct the issues the next day.

A.3 POST-PROCESSING

This phase is mainly concerned with the processing of the data based on the ground truth data collected in the previous phase.

The specific tasks in this phase are:

1. Creating a new vector files with polygons for training sites of the main crop classes using the ground truth data by digitizing the known crop areas and assign a unique ID for each crop type.

2. Before digitizing the areas, right click the new vector layer to Open Attribute Table and click Option and select Add Field to create a CropID field (short integer) and click OK.

3. Creating crop spectral signatures for supervised classification. Go to Spatial Analysis Tools> Multivariate> Create Signatures> add all the all the raster bands (i.e., 5 bands for RapidEye imagery)> Use the digitized crop polygon file (training sites) as "Input Raster or feature sample data", select the Crop ID field as "Sample field", and provide a path and file name in "Output signature file" box. Click "OK".

4. Performing a supervised classification with the crop spectral signatures to classify raster image by assigning each pixel to the crop type that has the most similar spectral signature by performing Maximum Likelihood Classification with all raster image bands and the signature file created in the previous step.

5. Converting the classified raster crop/landuse map to a vector map by using Conversion Tools>Raster to Polygon.

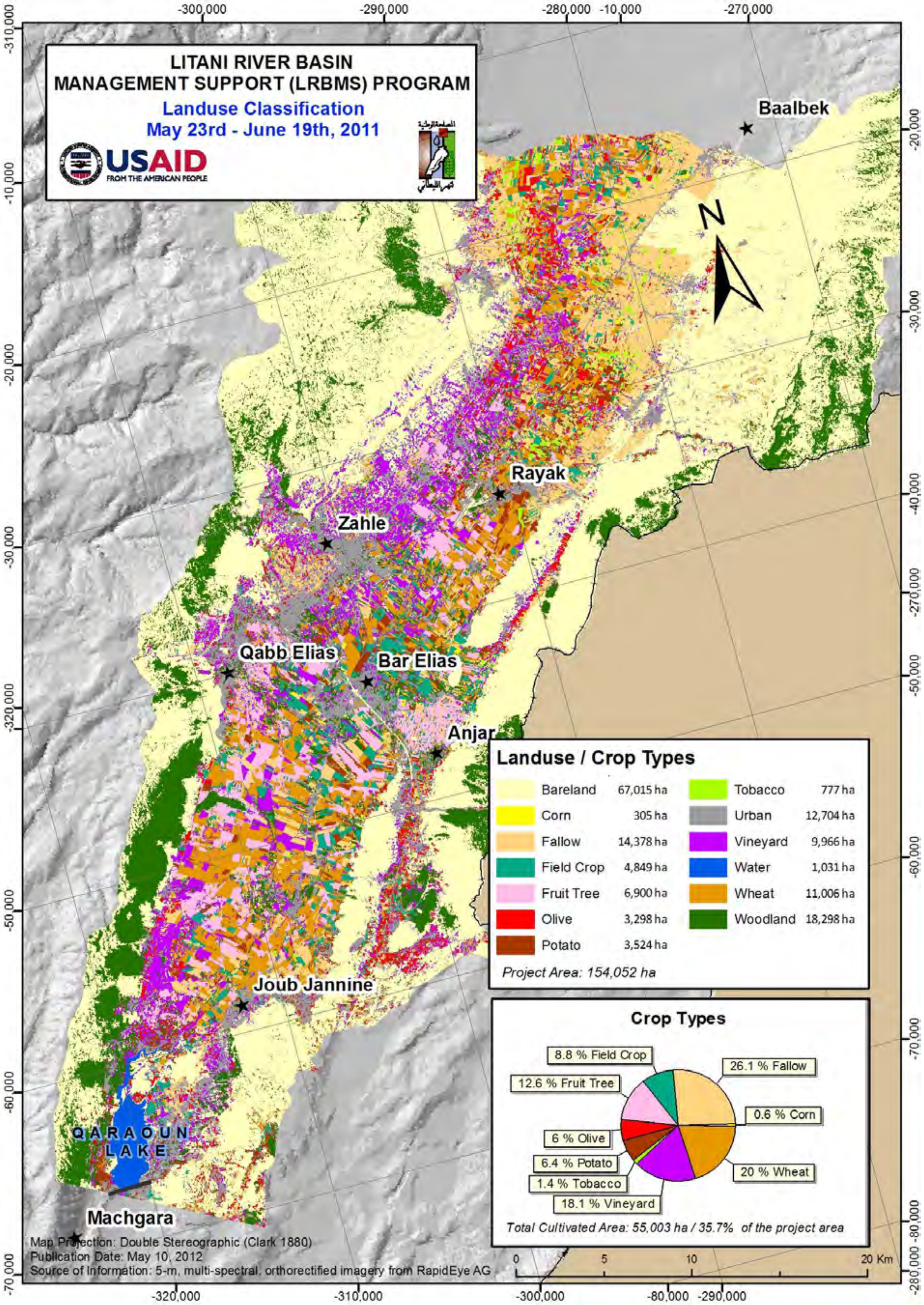
6. Computing area for each classified crop polygon. Open the attribute table of the vector crop map layer, add a new Area_M2 field and right clicking the Area_M2 field in its attribute table, select Calculate Geometry to compute area for each crop polygon.

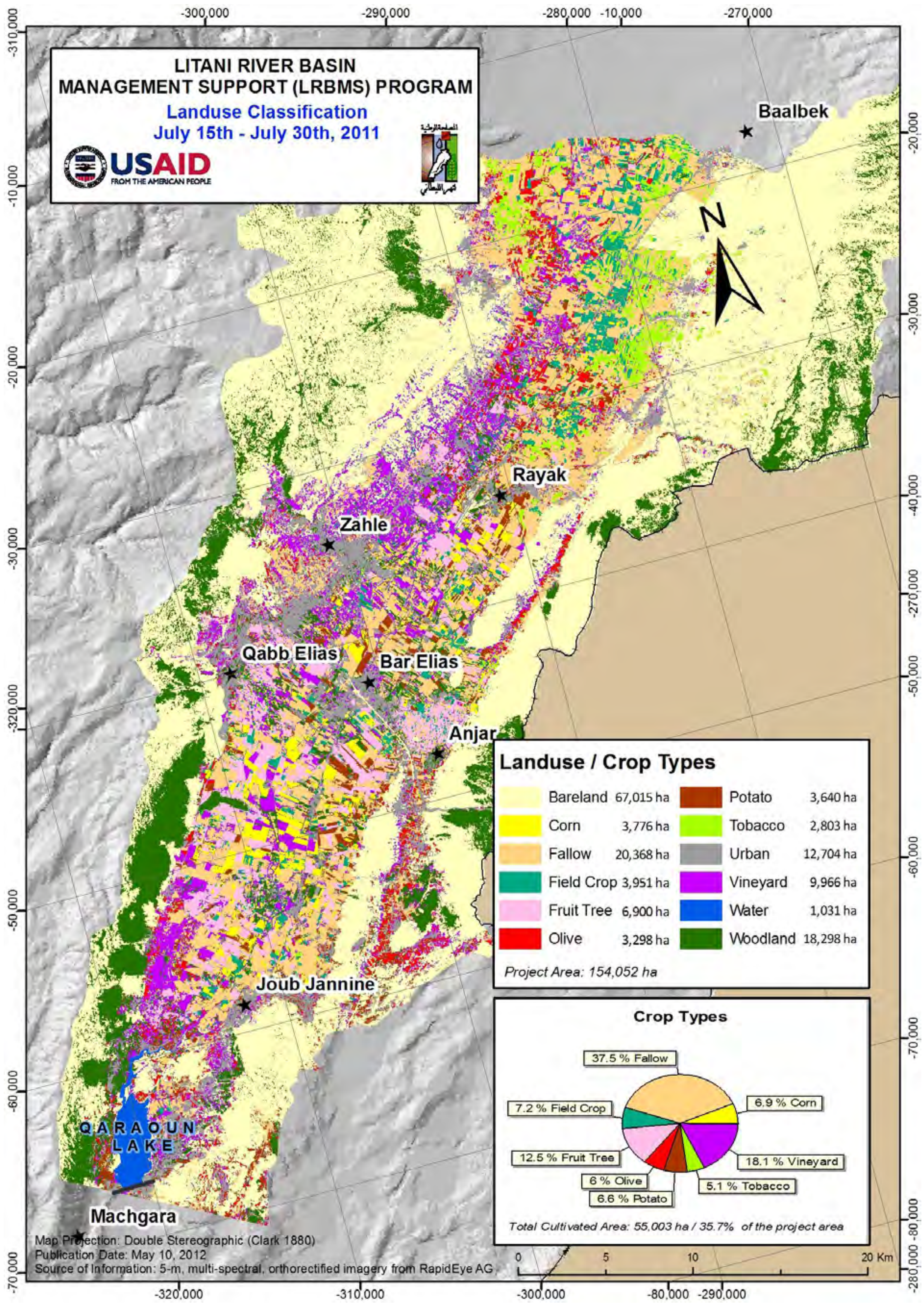
7. Summarizing area for each crop type. Right clicking the Area_M2 field in the attribute table, select CropID for “1. Select a field to Summarize”, and click Area_M2, select “Sum” to get a total area for each crop type under “2”. Chose one or more summary statistics to be included in the output table”. Click OK to generate the summary table.

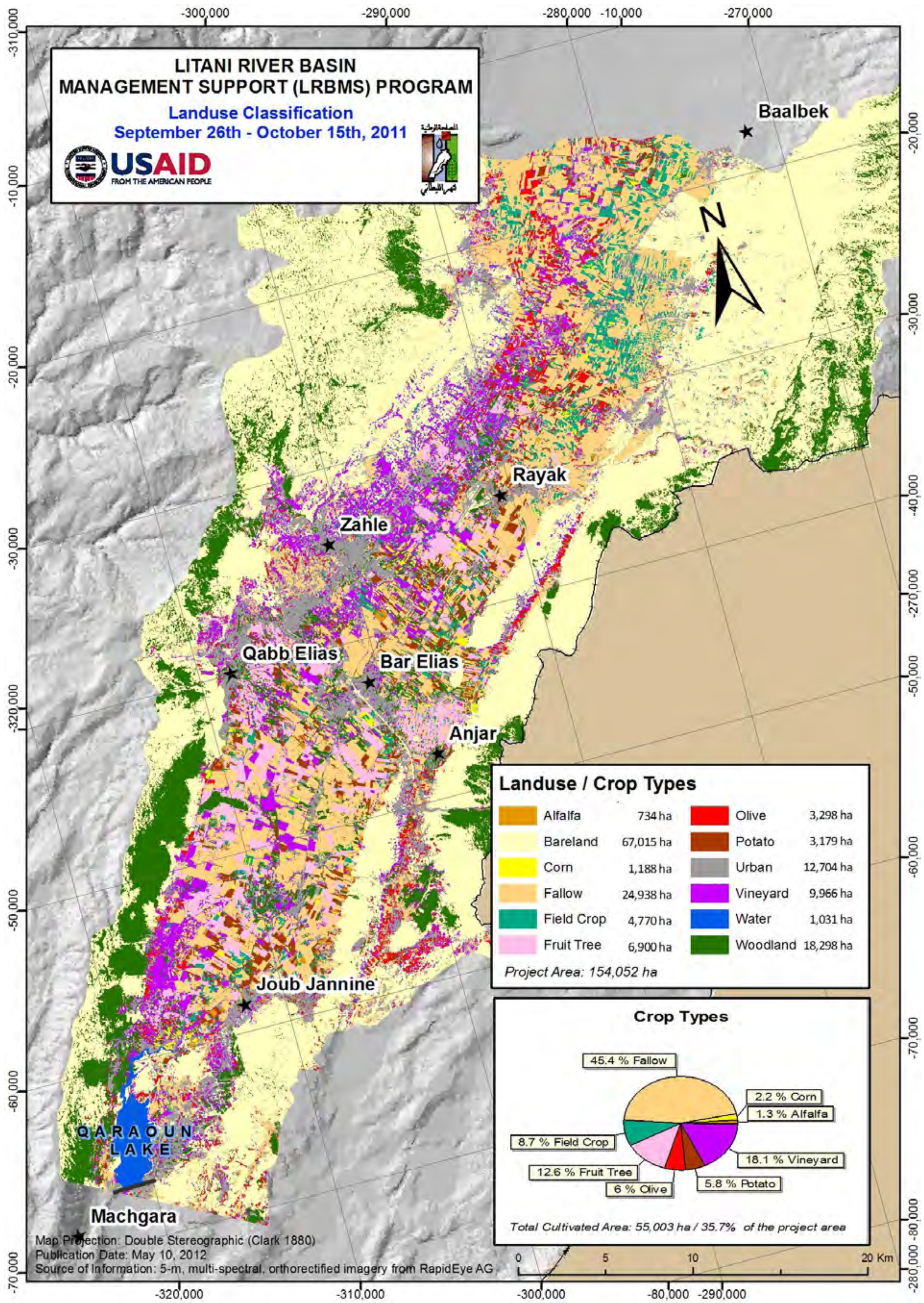
8. Confirming the classified crops cover at least 95 % of the entire cropped area in the Upper Litani River Basin.

9. Inspecting the results by comparing Google Earth imagery and other ancillary data for the same area. Collect new signatures, modify existing ones, or delete bad signatures if necessary and rerun your classification until you achieve acceptable results.

APPENDIX B: 2011 LANDUSE MAPS OF THE UPPER LITANI RIVER BASIN


LITANI RIVER BASIN
MANAGEMENT SUPPORT (LRBMS) PROGRAM
Landuse Classification
May 23rd - June 19th, 2011
USAID
FROM THE AMERICAN PEOPLE
Baalbek
Rayak
Zahle
Qabb Elias
Bar Elias
Anjar
Joub Jannine
QARAOUN LAKE
Machgara
N
Landuse / Crop Types
Bareland 67,015 ha
Corn 305 ha
Fallow 14,378 ha
Field Crop 4,849 ha
Fruit Tree 6,900 ha
Olive 3,298 ha
Potato 3,524 ha
Tobacco 777 ha
Urban 12,704 ha
Vineyard 9,966 ha
Water 1,031 ha
Wheat 11,006 ha
Woodland 18,298 ha
Project Area: 154,052 ha
Crop Types
8.8 % Field Crop
26.1 % Fallow
12.6 % Fruit Tree
0.6 % Corn
6 % Olive
6.4 % Potato
20 % Wheat
1.4 % Tobacco
18.1 % Vineyard
Total Cultivated Area: 55,003 ha / 35.7% of the project area
Map Projection: Double Stereographic (Clark 1880)
Publication Date: May 10, 2012
Source of Information: 5-m, multi-spectral, orthorectified imagery from RapidEye AG
0 5 10 20 Km
-300,000 -290,000 -280,000 -10,000 -270,000
-320,000 -310,000 -300,000 -80,000 -290,000


LITANI RIVER BASIN
MANAGEMENT SUPPORT (LRBMS) PROGRAM
Landuse Classification
July 15th - July 30th, 2011
USAID
FROM THE AMERICAN PEOPLE
Baalbek
Rayak
Zahle
Qabb Elias
Bar Elias
Anjar
Joub Jannine
QARAOUN LAKE
Machgara
N
Landuse / Crop Types
Bareland 67,015 ha
Corn 3,776 ha
Fallow 20,368 ha
Field Crop 3,951 ha
Fruit Tree 6,900 ha
Olive 3,298 ha
Potato 3,640 ha
Tobacco 2,803 ha
Urban 12,704 ha
Vineyard 9,966 ha
Water 1,031 ha
Woodland 18,298 ha
Project Area: 154,052 ha
Crop Types
37.5 % Fallow
6.9 % Corn
7.2 % Field Crop
12.5 % Fruit Tree
18.1 % Vineyard
6 % Olive
6.6 % Potato
5.1 % Tobacco
Total Cultivated Area: 55,003 ha / 35.7% of the project area
Map Projection: Double Stereographic (Clark 1880)
Publication Date: May 10, 2012
Source of Information: 5-m, multi-spectral, orthorectified imagery from RapidEye AG
0 5 10 20 Km


LITANI RIVER BASIN
MANAGEMENT SUPPORT (LRBMS) PROGRAM
Landuse Classification
September 26th - October 15th, 2011
USAID
FROM THE AMERICAN PEOPLE
Baalbek
Rayak
Zahle
Qabb Elias
Bar Elias
Anjar
Joub Jannine
QARAOUN LAKE
Machgara
Landuse / Crop Types
Alfalfa 734 ha
Bareland 67,015 ha
Corn 1,188 ha
Fallow 24,938 ha
Field Crop 4,770 ha
Fruit Tree 6,900 ha
Olive 3,298 ha
Potato 3,179 ha
Urban 12,704 ha
Vineyard 9,966 ha
Water 1,031 ha
Woodland 18,298 ha
Project Area: 154,052 ha
Crop Types
45.4 % Fallow
2.2 % Corn
1.3 % Alfalfa
8.7 % Field Crop
18.1 % Vineyard
12.6 % Fruit Tree
6 % Olive
5.8 % Potato
Total Cultivated Area: 55,003 ha / 35.7% of the project area
Map Projection: Double Stereographic (Clark 1880)
Publication Date: May 10, 2012
Source of Information: 5-m, multi-spectral, orthorectified imagery from RapidEye AG
0 5 10 20 Km

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